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The Quality of Lake of the Ozarks

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A
SUMMARY REPORT
ON
THE QUALITY
OF
LAKE OF THE OZARKS

10/75-#15249

ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE - REGION VII
1735 BALTIMORE, KANSAS CITY, MO. 64108

JUNE 1972

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A C K N O W L E D G E M E N T

The field work described herein was completed with the assistance from numerous local citizens, the Lake of the Ozarks Area Development Council, the Missouri Clean Water Commission and other Federal Agencies. The assistance of all of those involved is gratefully acknowledged.

I N T R O D U C T I O N

Lake of the Ozarks in Central Missouri is a well-known tourist and recreation area in Midwest. It currently attracts nearly six million visitors yearly to enjoy its picturesque waters and scenic hills. The Lake area grows from twenty-five to thirty thousand permanent residents, to a population of about one-hundred thousand during the summer season. These people come to utilize the many tourist and recreation facilities available, generating sixty million dollars in the economy of the Lake region. The Lake also fosters a rapidly growing retirement settlement, principally of people from the large cities seeking the peace of a life close to nature.

Bagnell Dam, which created Lake of the Ozarks, was begun by Union Electric Company on August 6, 1929. Power generation began two years later on October 16, 1931. The one-half mile long dam on the Osage River impounds 2,100,000 acre-feet of water covering an area of ninety-three square miles. Located in Missouri, the dam is 172 miles from St. Louis, 150 miles from Kansas City and 42 miles from Missouri's capital in Jefferson City.

During the period between September 1970 and October 1971, the U. S. Environmental Protection Agency conducted water quality investigations of Lake of the Ozarks. The purpose of these studies was to provide technical information for the development of a regional water quality management plan. Specifically the studies were conducted: 1) To document the present physical, chemical and biological quality of the Lake of the Ozarks; 2) To evaluate the existing waste treatment facilities discharging into the Lake or its tributaries; and 3) To develop a comparison of → p 2

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selected water quality parameters during the spring and summer seasons.

The approach selected to provide information to meet these objectives was a combination of monitoring on a monthly frequency and short period intensive surveys. The monthly sampling occurred at 21 stations during the period September 1970 to October 1971, and intensive surveys were conducted during May and July of 1971. All sampling and analytical procedures were conducted in accordance with Standard Methods (1) or Environmental Protection Agency Methods (2).

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The Lake of the Ozarks is a popular resort area with summertime tourist and resident populations approaching one-hundred thousand. The availability of resort accommodations varying from the most elegant to the rustic fishing camp provides something for every taste. The Lake is also one of the few privately developed water bodies which allows development right to the high water mark.

Since the completion of Bagnell Dam in 1931, developments on the Lake shore line have been poorly controlled. This lack of planned development has threatened the Lake water quality. Recognition of the situation by a concerned populace has stimulated governmental agencies to implement water quality management planning studies to protect the resource. To support the joint planning efforts the Environmental Protection Agency conducted extensive field studies of the Lake. The findings and conclusions from these studies are:

1. The existing Lake water quality, based on 1970 - 1971 observations, is good and, except for localized areas, the Lake water is suitable for all recreational use.
2. Certain tributaries to the Lake carry large amounts of particulate material with a high iron content from coal strip mine areas.
3. Periods of intense rainfall increase the bacterial load discharged to the Lake by tributaries due to land runoff.
4. Visual observations and turbidity measurements show a reduction in turbidity in the downstream direction. Consequently, the

area from the dam to approximately Hurricane Deck is more appealing aesthetically.

5. Drainage from septic tank leach fields was not readily apparent from the results in this study. Densities of fecal coliforms were essentially the same in May and July in a small cove whose shore line was almost completely developed in cabins and permanent residences.

6. The results of intensive bacteriological sampling in May and July at the Millstone Lodge and Holiday Inn Marinas show only slight increases in organism density during the heavy use period. In all cases the mean organism density was significantly lower than the standard established by the State of Missouri for water contact sports.

7. The occurrence of nuisance plant growths, either phytoplankton or rooted aquatics, was not reported or detected during the study period. Studies of primary productivity demonstrated a mesotrophic or moderately enriched condition. During the May and July observations, the carbon fixation rates appeared to be limited by a lack of soluble phosphorus.

8. Major sources of nutrients which could stimulate plant growths are the tributary inflows, leachate from septic tanks, boat wastes and discharges from municipal and resort sewage treatment facilities. Of these sources, the ones most easily controlled are the septic tanks and the municipal and resort waste treatment facilities. Boat wastes will be subject to control through stringent state regulation under a recently enacted Missouri law and pending Federal rules.

Based on these conclusions it is recommended additional studies be conducted to provide more information on the seasonal productivity

patterns and nutrient availability. Also, an effort should be made to monitor more residential shore line areas for septic tank drainage to define the magnitude of this problem.

RESULTS AND DISCUSSION

The Monitoring Studies were conducted during the period September 1970 - October 1971. This work involved monthly sampling at nine mid-channel stations and at twelve stations on tributary streams (Figure 1). The Appendix contains a list of stations sampled during the field investigations. The monitoring objective was to establish the existing water quality baseline for selected parameters. Selected data are shown in Tables 1 and 2.

Significant conclusions to be drawn from these Tables are:

1. Dissolved oxygen and biochemical oxygen demand concentrations, which are reliable indices of organic pollution, were at levels expected in natural waters relatively free from waste discharges.
2. Turbidities decrease progressively downstream in the Lake, indicating increased light penetration. Because of particle size, there is not a clear-cut correlation between turbidity and suspended solids concentration. Turbidities in the tributaries were variable due to size and location of the stream.
3. During the study period no phytoplankton blooms of nuisance proportions were observed. Concentrations of major growth-stimulating nutrients, nitrogen and phosphorus, were near or below levels necessary to promote and sustain blooms.
4. Iron concentrations in the upstream portions of the Lake were high due to tributary influence. These concentrations are indicative of drainage from the strip mining area in Eastern Kansas and Western Missouri.

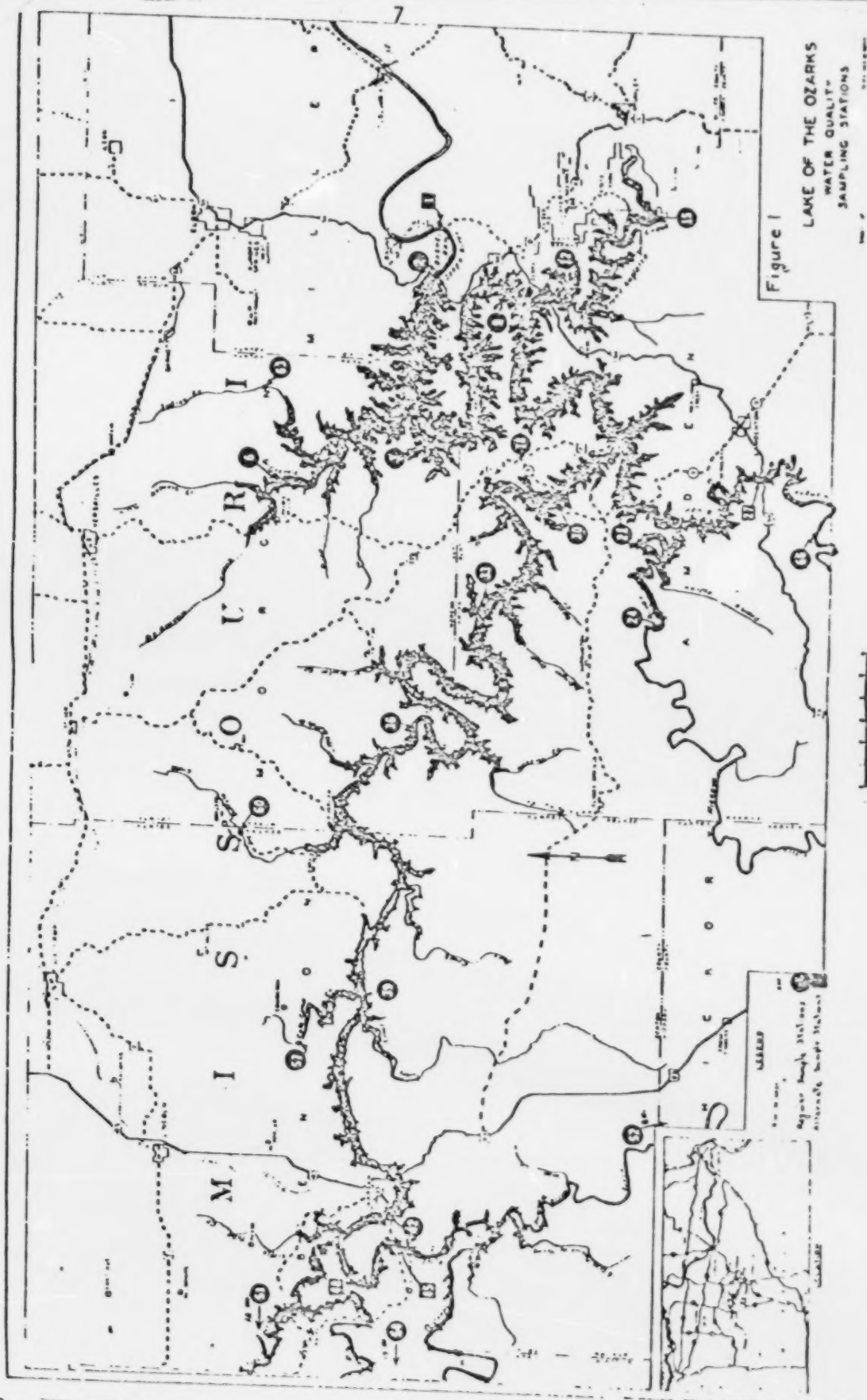


TABLE 1
LAKE OF THE OZARKS
MEAN VALUES OF SELECTED WATER QUALITY PARAMETERS IN THE MAIN LAKE CHANNEL
SEPTEMBER 1970 - OCTOBER 1971

STATION	BIOCHEMICAL		(ALL SAMPLES FROM ONE FOOT DEPTH)							
	DISSOLVED OXYGEN mg/l	OXYGEN DEMAND mg/l	TURBIDITY JTU	SUSPENDED SOLIDS mg/l	DISSOLVED SOLIDS mg/l	NITRATE-N mg/l	ORTHO-PHOSPHATE As P mg/l	IRON mg/l	FECAL COLIFORM pf/100 ml	
L0-42 Lake of the Ozarks at Missouri Highway 7 Bridge	9.2	2.4	46	210	225	0.75	0.09	1.57	470	
L0-39 Lake of the Ozarks Main Channel 3 miles West of Lake View Heights	8.5	2.2	41	189	287	0.65	0.08	1.55	120	
L0-36 Lake of the Ozarks 4 miles Southeast of Procter (68.3 miles upstream from dam)	8.9	2.5	32	190	283	0.49	0.08	1.62	60	
L0-33 Lake of the Ozarks (17.5 miles upstream from dam)	8.5	1.9	24	179	253	0.63	0.09	1.20	10	
L0-18 Lake of the Ozarks (25.3 miles upstream from dam)	8.5	1.0	13	192	218	0.62	0.09	0.73	3	
L0-9 Lake of the Ozarks Perken Point (4.1 miles upstream from dam)	9.3	1.1	14	183	206	0.57	0.06	0.85	8	
L0-3 Lake of the Ozarks Main Channel mouth of Gravois Arm	9.1	1.1	12	206	228	0.65	0.10	0.64	40	

TABLE 2
LAKE OF THE OZARKS
MEAN VALUES OF SELECTED WATER QUALITY PARAMETERS IN STREAM TRIBUTARY TO LAKE OF THE OZARKS
SEPTEMBER 1970 - OCTOBER 1971

STATION	DISSOLVED OXYGEN mg/l	BIOCHEMICAL OXYGEN DEMAND mg/l	TURBIDITY JTU	SUSPENDED SOLIDS mg/l	DISSOLVED SOLIDS mg/l	NITRATE-N mg/l	ORTHO-PHOSPHATE mg/l	TOTAL IRON mg/l	FECAL COLIFORM MF/100 ml
L0-52 Pome de Terre River at US Highway 54	9.2	1.5	12	167	148	0.34	0.08	0.63	140
L0-54 Osage River at Missouri Highway 13	9.2	2.8	158	270	224	0.77	0.04	4.40	2,100
L0-51 South Grand at County Road AA	8.4	3.1	120	337	215	0.84	0.06	4.50	1,900
L0-57 Cole Camp Creek near County Road H	9.7	1.7	13	158	190	0.56	0.08	0.63	30
L0-60 Big Buffalo Creek on County Road W	10.1	0.7	1	193	213	0.25	0.02	0.14	29
L0-24 Little Niangua River at County Road J	9.2	1.5	21	168	190	0.40	0.08	0.89	1,600
L0-66 Niangua River near Highway US 54	8.9	1.3	12	253	189	0.53	0.06	0.58	170
L0-15 Grand Auglaize Arm at State Park launch ramp	9.3	1.9	18	162	174	0.27	0.05	0.91	240
L0-6 Gravois Arm near Gravois Mill	9.1	1.5	11	248	183	0.35	0.13	0.36	40
L0-63 Indian Creek at County Road W	8.1	0.7	4	205	220	0.21	0.01	0.55	310

1/ Fecal Coliform densities in tributary streams influenced by runoff. Mean densities reported reflect some storm runoff influence.

5. Monitoring data for fecal coliform indicate significant densities for one Lake station and for several tributaries. These levels are attributable to samples collected during high water periods. At normal flow conditions the observed densities were below levels established for whole body contact recreation, i.e. 200 organisms per 100 ml.

Results of the intensive bacteriological studies in May and July of 1971 are shown in Tables 3 and 4. The data in these Tables are arithmetic means of five to seven analyses. Figure 2 is a graphical representation of all of the data and presents the significant trends. The bacterial densities in the cove surrounded by residences show little difference between May and July. The seasonal numerical difference shown by the plot for Millstone Cove is somewhat higher, reflecting the heavier summer use. The Holiday Inn Cove, which receives the effluent from the Inn Sewage Treatment Plant, shows the greatest increase in bacterial densities.

At the present time there are four distinct sources of pollutants reaching the Lake: tributary streams which carry wastes discharged by communities and overland runoff from precipitation; treated wastes discharged directly into the Lake by communities and resorts; leachate from septic tanks serving residences and resorts on the Lake shore; and direct waste discharge from boats and from marinas.

The two largest municipal discharges affecting the Lake of the Ozarks are Camdenton (population approximately 1,600) and Warsaw (population approximately 1,200). Camdenton's treatment facilities consist of seven widely scattered lagoons. All of these facilities

TABLE 3

Summary of Observed Fecal Coliform Densities
in a Cove Surrounded by Residential Development

Lake of the Ozarks

May and July 1971

STATION		MEAN ^{1/} COLIFORM DENSITY MF/100ML	
		MAY	JULY
LO 101	Main Lake Channel at Mouth of Study Cove	2	2
LO 102	Mouth of Study Cove	6	2
LO 103	1,000 Feet from Mouth Center Line of Study Cove	17	100 ^{2/}
LO 104	2,500 Feet from Mouth Center Line of Study Cove	6	2
LO 105	4,000 Feet from Mouth Center Line of Study Cove	8	5
LO 106	Open Water - Study Cove SE Corner	6	2
LO 107	Near Shore SE Corner	11	5
LO 108	Open Water - NW Corner	19	3
LO 109	Open Water - NW Corner	13	5
LO 110	Open Water - NW Corner	12	6
LO 111	Near Shore North End	15	12
LO 112	Near Shore NE Corner	5	4
LO 113	Near Shore NE Corner	3	7
LO 114	Open Water Southeast	3	3
LO 115	Near Shore SE Corner	N ^S ^{3/}	2

^{1/} Arithmetic means based on five observations from samples collected before noon

^{2/} One value of 480 organisms per 100 ml all others less than 10

^{3/} Not sampled in May

TABLE 4

Summary of Fecal Coliform Data in Two
Lake of the Ozark Coves with Resort Marinas

May and July 1971

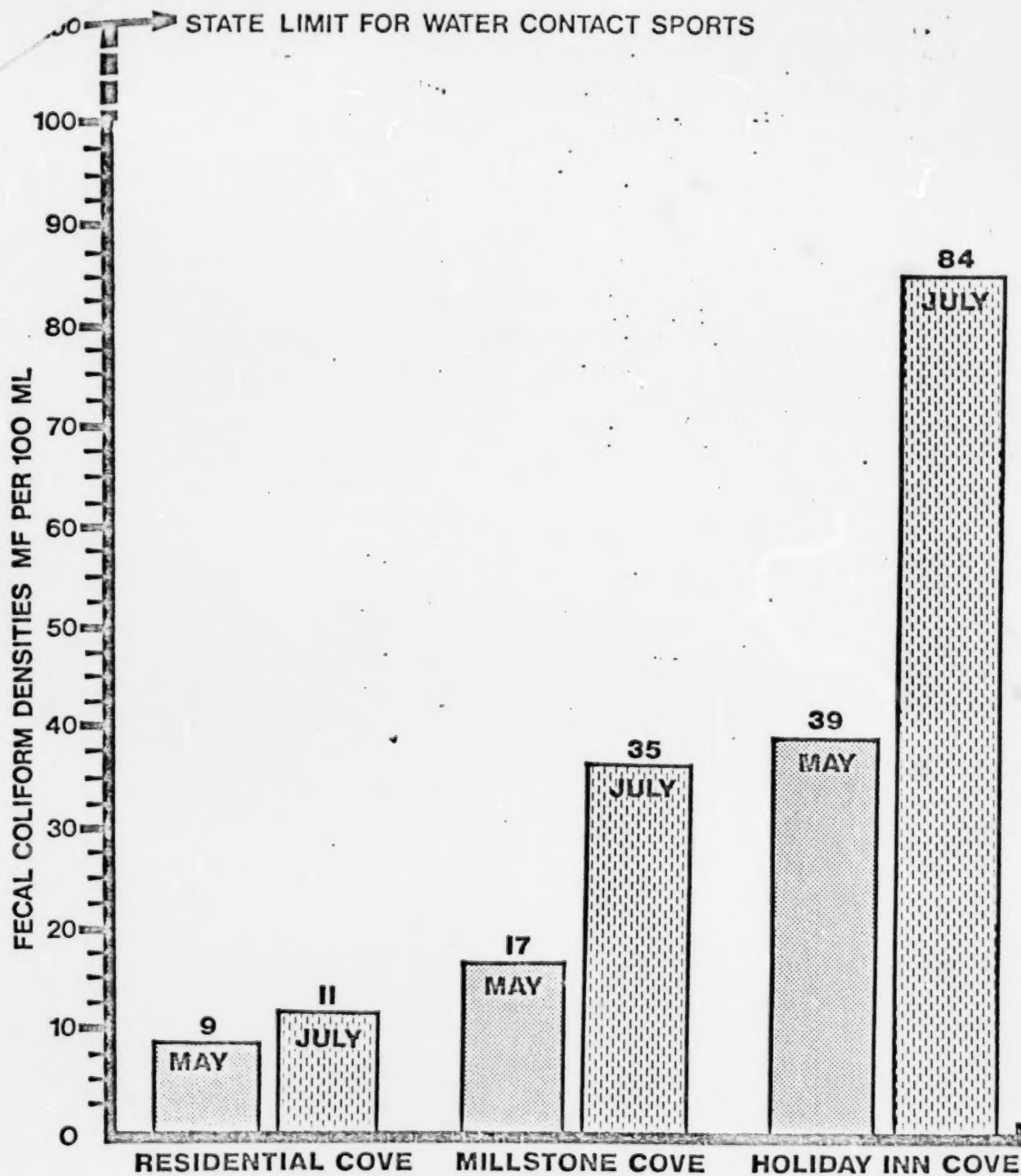
STATION		FECAL COLIFORM DENSITIES MF/100ml	
		May 1/	July 2/
MILLSTONE LODGE COVE			
LO 117	SW Corner of Cove	7	18
LO 118	West Edge of Cove	9	25
LO 119	NW Corner of Cove	25	52 <u>3/</u>
LO 120	North End of Cove	25	28
LO 121	Northeast Corner of Cove	12	10
LO 122	Southeast Corner of Cove	27	32
LO 123	Lodge Swimming Area	13	78 <u>3/</u>
HOLIDAY INN COVE			
LO 124	SE End South Cove	28	170 <u>4/</u>
LO 125	Center of South Cove	35	110 <u>3/</u>
LO 126	NE end of South Cove	37	88 <u>3/</u>
LO 127	Lake in Front of Inn	62	50
LO 128	West end of North Cove	27	61
LO 129	Center of North Cove	42	51
LO 130	East End of North Cove	Not Sampled	55

1/ Based on five daily samples

2/ Based on seven daily samples including weekend

3/ One observation in excess of 200 organisms/100 ml

4/ Three values in excess of 200 organisms/100ml



FECAL COLIFORM DENSITIES

Lake Of The Ozarks
May and July 1971

(Figure 2)

discharge eventually into the Lake. Warsaw is served by a hydrolytic tank, followed by a lagoon which discharges into the Osage River. Data from composite samples from the South Camdenton Lagoon discharging into Minow Creek and from the Warsaw Lagoon are shown in Table 5.

The May data for Camdenton reflect a very weak waste. There was no overflow in July and no data are shown. The data for Warsaw reflect a better degree of treatment in May than July. Both systems contribute nutrients to the Lake drainage.

Wastes discharged by the resorts were characterized by the measurements of the effluent waste treatment facilities at Holiday Inn.

The Holiday Inn is employing three extended aeration plants for treatment of its wastes. Two of these discharge through what will be referred to as the South Plant and the other plant will be referred to as the North Plant. Six-hour composite samples were collected from each of these plants May 28, 1971, and July 28, 1971.

During the May effort, the North Plant achieved seventy percent non-filterable solids reduction and eighty percent BOD reduction. The South Plant achieved forty-two percent non-filterable solids reduction and eighty-three percent BOD₅ reduction. During this effort both of these plants were operating below achievable efficiencies.

During the July effort the Holiday Inn plants were combined for compositing purposes because of their relatively low flow. The plants at this time achieved ninety percent BOD₅ reduction and appeared to be functioning properly. The data from the Holiday Inn study are shown in Table 6.

TABLE 5

WASTE TREATMENT LAGOON ANALYSES
CAMDENTON AND WARSAW MISSOURI
MAY AND JULY 1971

(VALUES IN MG/L)

CAMDENTON COMPOSITE SAMPLE
May 27, 1971

	<u>Nonfilt Solids</u>	<u>NH₃ N</u>	<u>Org N</u>	<u>NO₃-NO₂ N</u>	<u>Ortho P</u>	<u>Total P</u>	<u>COD</u>	<u>BOD₅</u>
Upstream	--	0.05	0.15	0.47	0.00+	0.03	3	1.4
Influent	55	11	4	0.20	2.00	2.70	92	54
Effluent	67	0.65	7.4	0.11	0.38	1.20	124	28
Downstream	--	0.54	0.47	*	0.06	0.09	19	3.0

* No Result

NO JULY SAMPLE FOR CAMDENTON BECAUSE OF NO DISCHARGE

WARSAW COMPOSITE SAMPLE
May 26, 1971

	<u>Nonfilt Solids</u>	<u>NH₃ N</u>	<u>Org N</u>	<u>NO₃-NO₂ N</u>	<u>Ortho P</u>	<u>Total P</u>	<u>COD</u>	<u>BOD₅</u>
Upstream	--	0.17	1.55	0.51	--	--	10	4.1
Influent	116	23	14	0.03	13	13	317	154
Effluent	210	1.15	5.0	0.09	.39	.51	110	30
Downstream	--	0.35	.55	0.53	.03	.07	41	3.8

WARSAW COMPOSITE SAMPLE
July 26, 1971

	<u>COD</u>	<u>BOD₅</u>
Upstream	12	2.7
Influent	236	164
Effluent	94	15
Downstream	10	2.2

None of the sampling stations included in this investigation reflected any direct changes in water quality due to septic tank leachate, which indicates that there were no measurable changes during the times and at the location where samples were taken. The available data on this problem for Lake of the Ozarks are insufficient to draw any major conclusions. Further study should be undertaken because of the potential seriousness of the problem.

Wastes from vessels and marinas are subject to control through existing state legislation and soon to be released Federal Regulations. The State Laws will require holding tanks and prohibit the discharge of wastes from vessels except at approved pumpout station. The wastes near marinas can be controlled through better employee training, better house-keeping and stronger enforcement of anti-litter laws. Almost all of the material entering the water at marinas is due to carelessness.

The last phase of the Environmental Protection Agency investigation was a study of primary production in the Lake. Two coves were selected for study to provide a comparison between productivity rates and the degree of shoreline development. Four stations at each cove (Figure 1) were sampled for productivity rates for ten days during each sampling period (May and July 1971).

The depth of the euphotic zone (the region that receives one percent or more of surface illumination) was measured daily with a submarine photometer. Temperature profiles were obtained using a precalibrated thermistor with a forty foot probe extension.

TABLE 6HOLIDAY SEWAGE TREATMENT PLANT
OPERATION DATA FOR MAY AND JULY 1971

(VALUES IN MG/L)

HOLIDAY INN NORTH PLANT

MAY 28, 1971

COMPOSITE SAMPLE DATA

<u>0600 to 1200</u>	<u>Nonfilt Solids</u>	<u>NH₃ N</u>	<u>Org N</u>	<u>NO₃-NO₂ N</u>	<u>Ortho P</u>	<u>Total P</u>	<u>COD</u>	<u>BOD₅</u>
Influent	72	5.5	42	0.36	4.90	7.50	125	106
Effluent	22	0.14	1.54	14.0	4.95	7.30	19	22

HOLIDAY INN SOUTH PLANT

MAY 28, 1971

COMPOSITE SAMPLE DATA

<u>0600 to 1200</u>	<u>Nonfilt Solids</u>	<u>NH₃ N</u>	<u>Org N</u>	<u>NO₃-NO₂ N</u>	<u>Ortho P</u>	<u>Total P</u>	<u>COD</u>	<u>BOD₅</u>
Influent	90	6.9	19	0.02	9.13	9.30	391	274
Effluent	52	2.3	4.6	0.69	3.90	4.90	136	47

HOLIDAY INN - NORTH AND SOUTH PLANT COMBINED

JULY 28, 1971

COMPOSITE SAMPLE DATA

<u>0600 to 1200</u>	<u>COD</u>	<u>BOD₅</u>
Influent	340	153
Effluent	89	16

At each station, five increments of depth were sampled (1, 5, 10, 15, and 35 feet) for the entire photo period of each day. Primary productivity measurements were obtained using the oxygen uptake method (3) with modifications outlined in Standard Methods (1).

All water samples for chemical analysis were collected, preserved, and analyzed following EPA's procedures (2). Plankton samples were identified and enumerated according to procedures in Standard Methods (1).

All values presented in the tables and figures, unless otherwise noted, are calculated averages for the four stations at each cove.

During May 1971, the two study coves did not have definable thermoclines (Figure 3). Water temperatures ranged from 15°C at the surface to 12°C at the 35' depth. Dissolved oxygen concentrations from surface to the 40' depth ranged from 11.40 mg/l to 7.20 mg/l, respectively. Previous studies (4) indicated that the reservoir becomes thermally stratified during the latter part of May and remains stratified through October. Figure 4 illustrates the dissolved oxygen and temperature profiles for July which indicate stratification was occurring.

The phytoplankton collected during the May survey were primarily centric diatoms. Table 7 lists the types and relative abundance of phytoplankton during both sampling periods. The diatoms Melosira and Cyclotella which were the predominate genera during the spring months are common during spring blooms in bodies of water classified as "mesotrophic" (moderately enriched). The July sampling period revealed that the coccoid green algal forms were predominate in the collections but few in numbers (<1,500/ml). Reservoirs which are mesotrophic

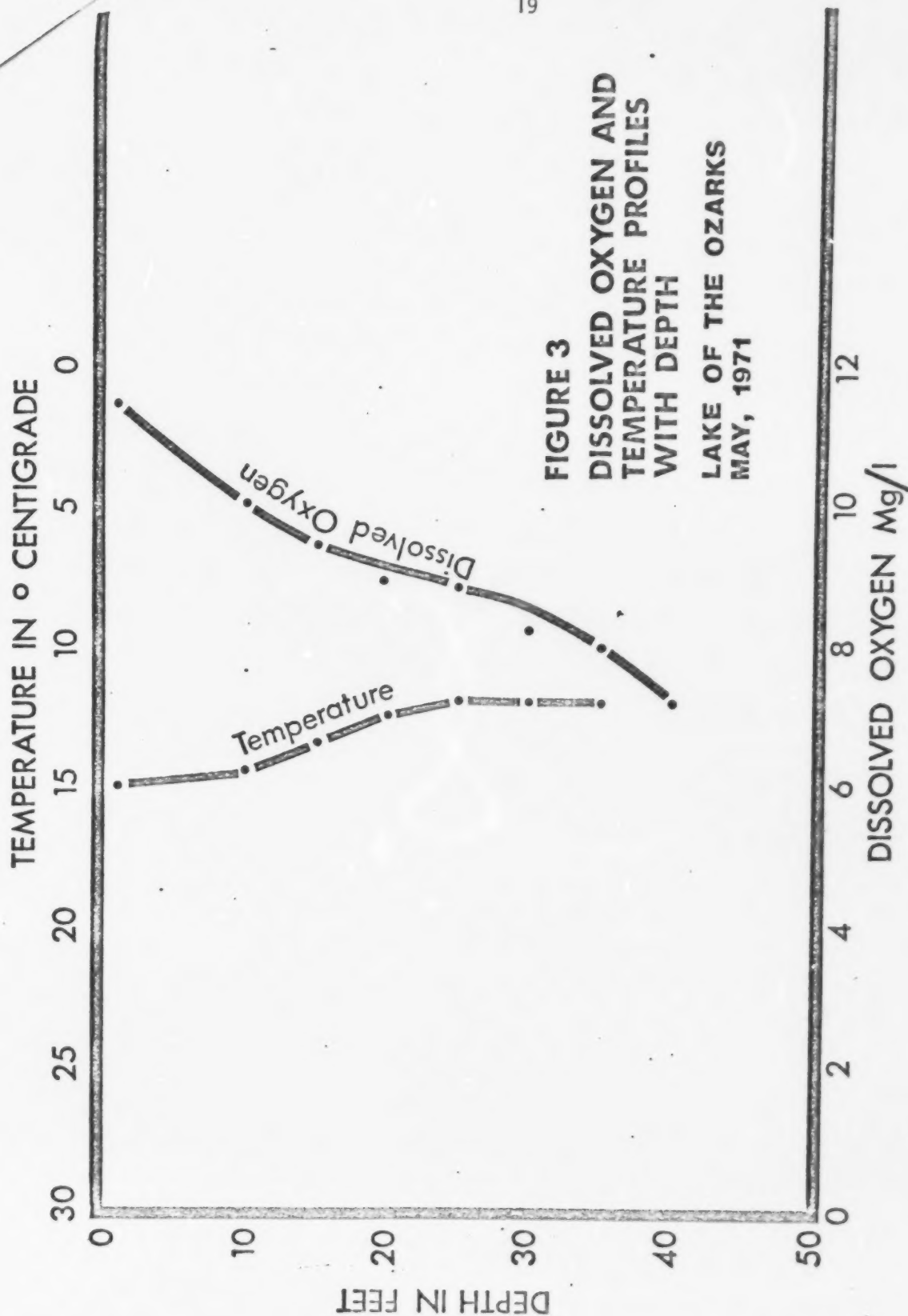
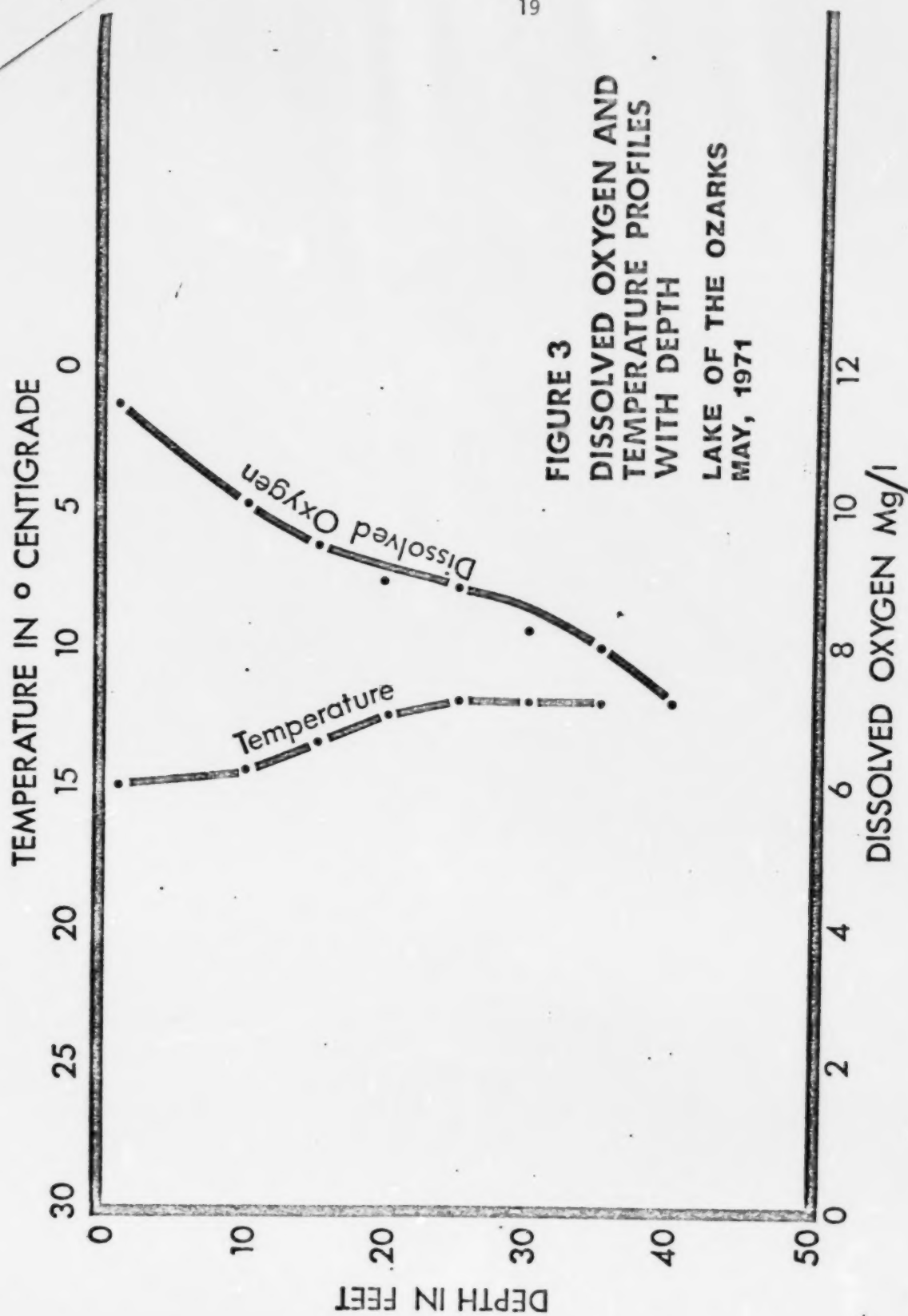


FIGURE 3
DISSOLVED OXYGEN AND
TEMPERATURE PROFILES
WITH DEPTH
LAKE OF THE OZARKS
MAY, 1971



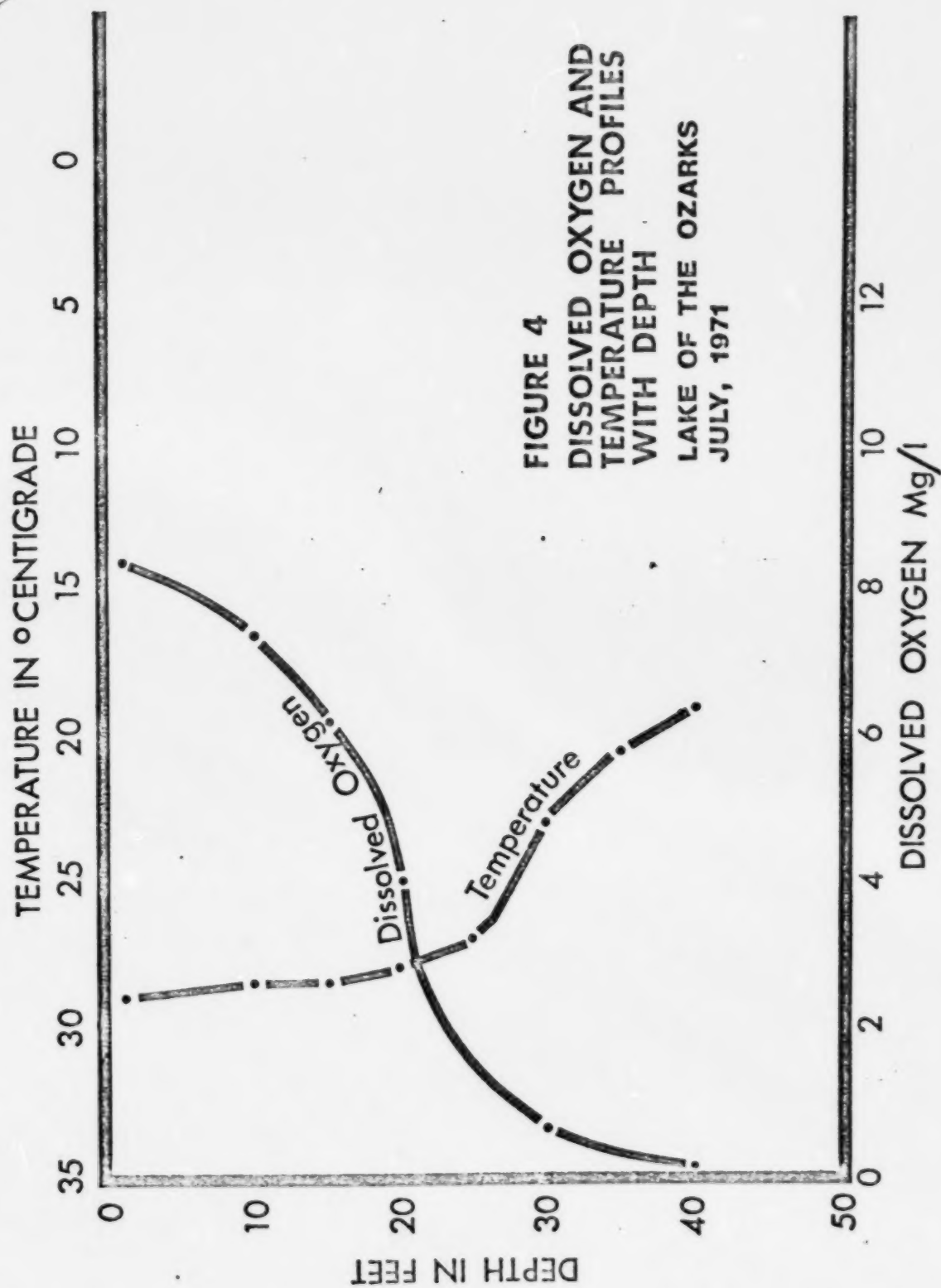


FIGURE 4
DISSOLVED OXYGEN AND
TEMPERATURE PROFILES
WITH DEPTH
LAKE OF THE OZARKS
JULY, 1971

TABLE 7

SUMMARY OF PHYTOPLANKTON COUNTS
WITH THE FOUR MOST ABUNDANT GENERA
LAKE OF THE OZARKS
MAY AND JULY 1971

May 1971

Heavy-Use Cove		Low-Use Cove	
Genera	No./ml	Genera	No./ml
Melosira	385	Melosira	365
Cyclotella	338	Cyclotella	356
Synedra	228	Synedra	261
Asterionella	66	Asterionella	132
Total Number	1,128	Total Number	1,298

July 1971

Heavy-Use Cove		Low-Use Cove	
Genera	No./ml	Genera	No./ml
Chlamydomonas	495	Chlorella	274
Kirchneriella	297	Scenedesmus	165
Chlorella	99	Chlamydomonas	165
Scenedesmus	33	Crucigenia	66
Total Number	2,221	Total Number	2,574

generally have phytoplankton standing crops of 5,000 cells/ml or more during the summer months (4).

Chemical analysis during both sampling periods revealed that the major algal growth nutrients, nitrogen and phosphorus, were near or below levels required for algal blooms (Tables 8 and 9). Surface waters from both coves had concentrations of inorganic nitrogen ranging from 0.50 to 0.85 mg/l and soluble phosphorus levels from nondetectable amounts to 0.01 mg/l. A survey of seventeen eutrophic lakes in Wisconsin (5) revealed that concentrations of 0.01 mg/l of soluble phosphorus and 0.30 mg/l of inorganic nitrogen at the time of spring overturn could stimulate algal blooms.

If the conditions in the selective study coves are representative of the entire Lake, it is apparent from reported concentrations of the macronutrients that soluble phosphorus is probably one of the limiting factors governing the development of excessive algal growths in the Lake of the Ozarks.

The rate of primary production is an index which may be used to classify waters and provide a relative estimate of phytoplankton populations and available nutrients. This measurement is defined as the rate of photosynthetic carbon fixation by plants (algae) and bacteria forming the base of the food chain.

Figures 5 and 6 illustrate the rate of primary production expressed as milligrams of carbon fixed per cubic meter per day ($\text{MgC/M}^3/\text{day}$) for both coves. The May period had the greatest rate of production occurring in the first few feet of the water column. The

TABLE 8

SUMMARY OF CHEMICAL AND BIOLOGICAL FINDINGS
 LOW-USE COVE - LAKE OF THE OZARKS
 MAY AND JULY 1971

	May 1971	July 1971
Gross Primary Production MgC/M ² /day	817.00	955.75
Depth of Euphotic Zone Feet	20	15
Phytoplankton No. Algae Cells/ml (1)	1,298	2,574
Total Phosphorus Total-P mg/l (1)	0.01	0.02
Soluble Phosphorus Ortho-P mg/l (1)	Not Detectable	0.01
Inorganic Nitrogen NO ₂ -NO ₃ -N mg/l (1)	0.85	0.09
Organic Nitrogen Org-N (1)	0.60	0.29

(1) Values For Surface Collections

TABLE 9
SUMMARY OF CHEMICAL AND BIOLOGICAL FINDINGS
HEAVY-USE COVE - LAKE OF THE OZARKS
MAY AND JULY 1971

	May 1971	July 1971
Gross Primary Production MgC/m ² /day	591.25	1,107.33
Depth of Euphotic Zone Feet	20	15
Phytoplankton No. Algae Cells/ml (1)	1,128	2,221
Total Phosphorus Total-P mg/l (1)	0.04 (2)	0.02
Soluble Phosphorus Ortho-P mg/l (1)	Not Detectable (2)	0.01
Inorganic Nitrogen NO ₂ -NO ₃ -N mg/l (1)	0.50 (2)	0.18
Organic Nitrogen Org-N mg/l (1)	0.44 (2)	0.36

(1) Values For Surface Collections

(2) Values Taken From Sampling Station In Main Body Of Lake
Outside Of Cove

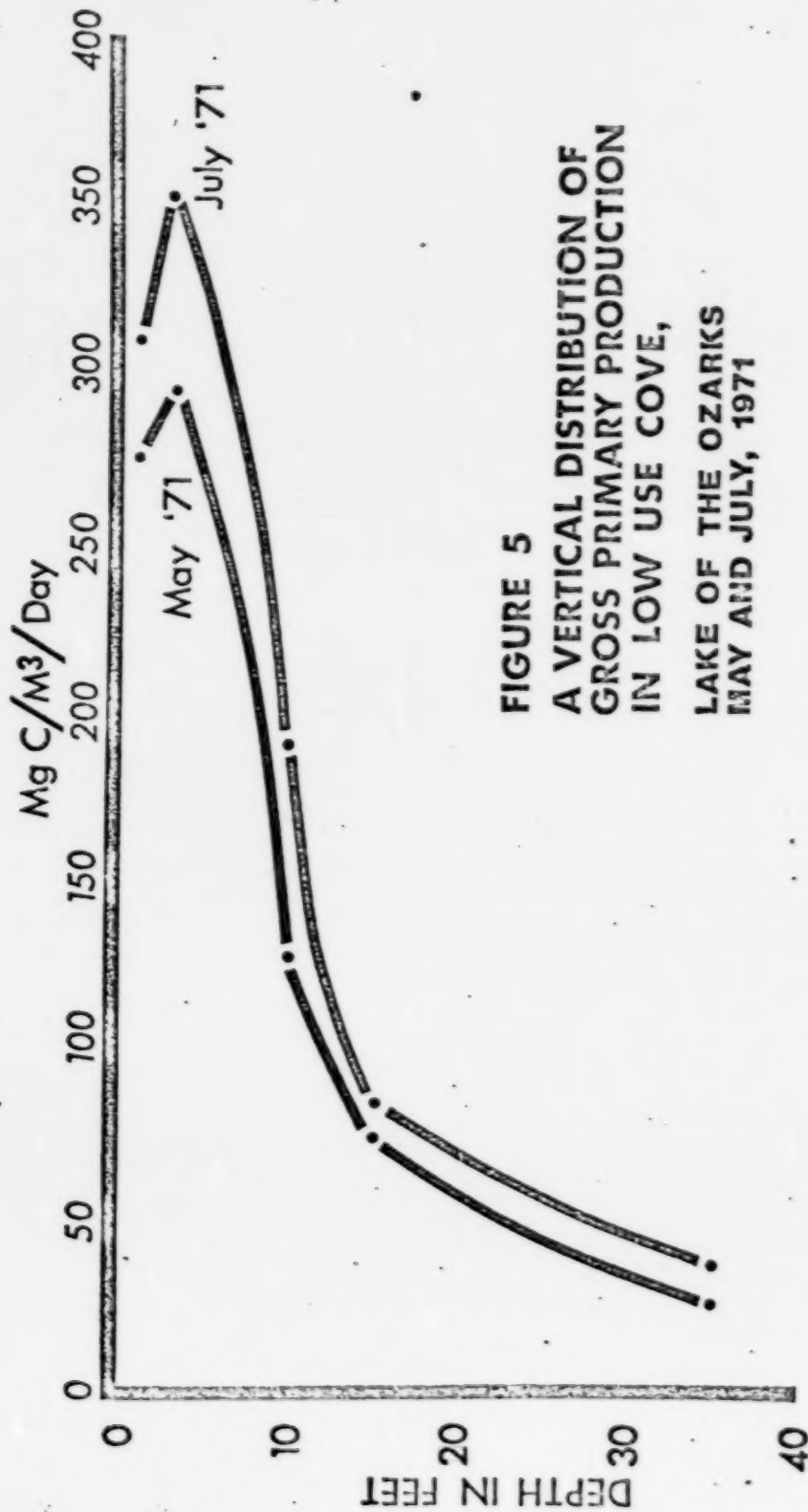


FIGURE 5
A VERTICAL DISTRIBUTION OF
GROSS PRIMARY PRODUCTION
IN LOW USE COVE,
LAKE OF THE OZARKS
MAY AND JULY, 1971

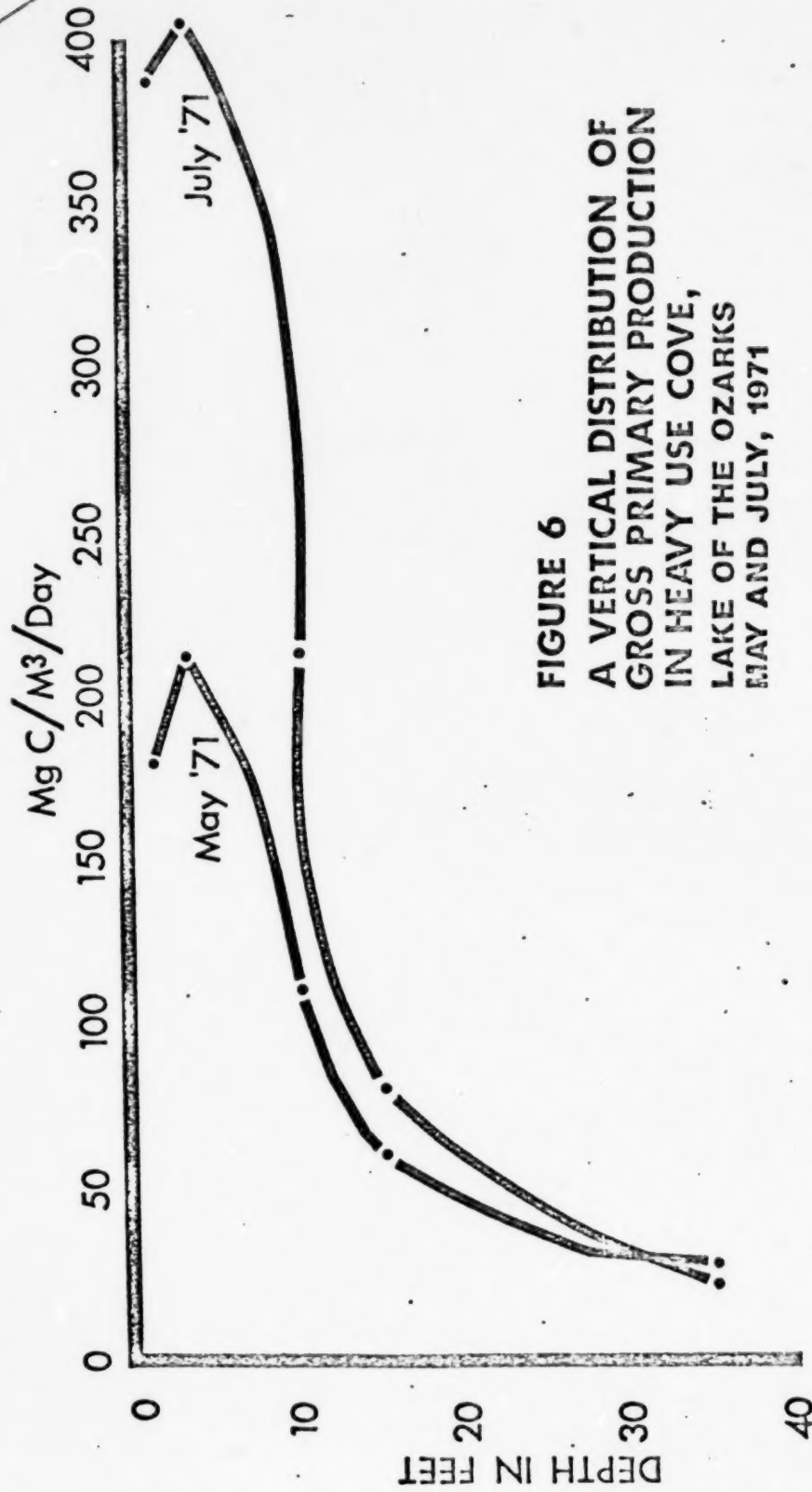


FIGURE 6
A VERTICAL DISTRIBUTION OF
GROSS PRIMARY PRODUCTION
IN HEAVY USE COVE,
LAKE OF THE OZARKS
MAY AND JULY, 1971

euphotic zone extended to the twenty-foot depth but the low volumetric values below the ten-foot depth indicated the scarcity of phytoplankton. The gross primary productivity during the May period ranged from 591 to 817 $\text{MgC/M}^2/\text{day}$ for the heavy and low-use coves, respectively.

Primary productivity rates increased in July at both coves but most notably at the heavy-use cove. The low-use cove rates increased slightly over the May values compared with the heavy-use cove where carbon fixation rates doubled (Tables 8 and 9).

In comparison with other lakes of similar size and age (6), Lake of the Ozarks is relatively unproductive in terms of phytoplankton standing crops and primary production.

The heavy-use cove in comparison with the low-use cove was the most productive in terms of carbon fixation. Chemical analyses of surface waters from this cove failed to detect levels of nutrients which could originate from inadequate sewage disposal. During both survey periods, the essential growth nutrients nitrogen and phosphorus were not in sufficient quantities to stimulate and sustain blooms of phytoplankton, thus restricting primary production.

REFERENCES

1. APHA, 1971. Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WPCF, 13th E., 874 pp.
2. Anon., 1971. Methods for Chemical Analysis of Water and Wastes, EPA, AQC, Cincinnati, Ohio, 312 pp.
3. T. Gaarder and H. H. Gran, 1927. Investigations of the Production of Plankton in the Oslo Fjord, Rapp. et proc. verb., J. Cons. Int. Explor. Mer. 42:1.
4. Anon., 1966. Biological Survey of the Lake of the Ozarks, June 7-10, 1966, USDI, FWPCA, Region VII, Unpublished Memorandum, 6 pp.
5. Sawyer, C. N., 1952. Some New Aspects of Phosphates in Relation to Lake Fertilization, Sewage and Industrial Wastes, 24 (6): pp. 768-776.
6. Taylor, Mahlon P., 1971. Phytoplankton Productivity Response to Nutrients Correlated with Certain Environmental Factors in Six TVA Reservoirs, Amer. Fish. Soc. Special Pub. #8, pp. 209-217.

A P P E N D I X

SAMPLING STATIONS
LAKE OF THE OZARKS
SAMPLED & ANALYSED BY
VARIOUS AGENCIES

<u>E.P.A. Station</u>	<u>C.O.E. Station</u>	<u>STORET Number</u>	<u>Description</u>
L0-42 & L0-136	1	280096	Hwy. 7 bridge at Warsaw
L0-45	1A	280097	Hwy. 7 bridge west of Warsaw
	1B	280098	Near Racket
	1C	280099	Northwest of Warsaw
	2	280100	East of Warsaw-Hwy. 65 bridge
	3 & 3A	280101	East northeast of Warsaw - Feaster bridge N. - Mile 87.9
	3B	280103	Near Warsaw
L0-39	4	280104	Near Cole Camp-Coll. Pt. - Mile 83.8
	5	280105	At Lakeview Heights-Bell Island - Mile 78.5
L0-36	6	280106	At Lumpee Island - Mile 68.3
	7	280107	At lookout tower-Coffman Bend - Mile 58.3
L0-33	8 & L8A	280109	At Bollinger Creek-Irontown Ferry - Mile 47.5
	8A	280110	At Hurricane Deck-Hahn Boy Scout Camp Swim Area
L0-30	9	280111	North crossing of Hwy. 5 Hurricane Deck Br. - Mile 37
L0-21	9A & N1	280112	South crossing of Hwy. 5 bridge - Niangua Arm
	9B	280113	Green Bay Terrace near Cedar Acres Store - Mile 31

<u>E.P.A. Station</u>	<u>C.O.E. Station</u>	<u>STORET Number</u>	<u>Description</u>
L0-18	10	280114	At Radio Tower-Turkey Bend near Tan-Tar-A - Mile 25.3
L0-9	11	280115	East of Sunrise Beach-Perkins Pt. - Mile 14.1
L0-3	11A	280116	N.W. of Sunrise Beach-North of Gravois
	G-3 11B	280117	Gravois Arm, Soap Creek Area
	12	280118	At Horseshoe Bend - Mile 4.1
	13	280119	Near Bagnell Dam - Mile 2.0
	14 1A	280120	Dam pool at Bagnell Dam
	N 1A	280122	Near Hwy. 5 on Niangua Arm
	N-2	280123	N.W. of Neongwah-Bridal Cave Dock
	N-3	280124	Hwy. 54 Southwest of Camdenton
	MT-1	280125	North of Zebra-Lower Glaize
	D-1	280126	Osage R. Tailrace-downstream side of dam
	D-2	280127	Osage R. 3.4 Miles downstream of Bagnell Dam
	D-2A	280128	Osage R. at Bagnell, Missouri
	D-3	280129	Osage R. 6.5 Miles downstream of Dam - N.E. of Bagnell Dam
	D-4	280130	Osage R. 10.3 Miles downstream of Dam - S.W. of Tuscumbia
	D-5	280131	Osage R. 15.8 Miles downstream of Dam at Tuscumbia
	G-1	280132	On Big Gravois Arm
	G-2	280133	Near Mill Creek
	G-4	280135	No. Holland Dock on Gravois Arm

<u>E.P.A. Station</u>	<u>C.O.E. Station</u>	<u>STORET Number</u>	<u>Description</u>
	G-A	280136	At Gravois Mills
	G-B	280137	On Gravois Arm-Millard's Luck Pt. Swim Area
		280138	Gatlins Boat Dock
	GG-1	280139	State Park Area-Girl Scout Swim Area
	GG-2	280140	Malibeu Beach-State Park Area
	GG-A	280141	Channel State Park # 1
	GG-B	280142	State Park Area
	GG-C	280143	State Park # 2
	L-1	280145	South Cove above Bagnall Dam
	LN	280146	Niangua Arm near Neongwah
	L-2	280147	Millstone Lodge Dock at Horse- shoe Bend
	L-3	280148	Sunrise Beach at Horseshoe Bend
	L-4	280149	Hwy. 54 at Holiday Inn
	L-4AA	280150	Lodge of the Four Seasons on Horseshoe Bend
	L-5	280151	Hwy. 54 bridge at Grand Glaize
	L-6	280152	Radio Tower at Tan-Tar-A Dock
	L-7	280153	Linn Cr. - Green Bay Terrace
	L-8	280154	De Laney Boat Yard - Lookout Tower
L0-1		280162	On left bank 1/2 mile S. of Bagnall
L0-6		280163	Lake of Ozarks in Gravois Arm
L0-12		280164	Lake of Ozarks Grand Auglaize Arm
L0-15		280165	Grand Auglaize Arm S.W. of Bramley

<u>E.P.A. Station</u>	<u>C.O.E. Station</u>	<u>STORET Number</u>	<u>Description</u>
L0-24 & LN-County J		280166	Little Niangua R. W.W. of Hurricane Deck
L0-27		280167	Lake of Ozarks W.S.W. of Camdenton
L0-48		280168	South Grand River W. of Warsaw
L0-51		280169	South Grand River 1 Mile N. of Brownington
L0-52		280170	Pomme De Terre River N.E. of Hermitage
L0-54		280171	Osage River N.E. of Osceola
L0-57		280172	Cole Camp Creek W. of Edmondson
L0-60		280173	Big Buffalo Creek S.W. of Boylers Mills
L0-63		280174	Indian Creek N.E. of Gravois Mills
L0-66		280175	Niangua River S.W. of Camdenton
L0-2		280155	At Bagnall Dam
L0-101		280248	Main channel of Lake of Ozarks at mouth of small cove on the North side of channel. 1 3/8 Mile West of Gravois Arm.
L0-102		280249	Mouth of study cove on North side of main channel of Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-103		280250	Center of study cove 1000 feet NW of its mouth on north side of main channel of Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-104		280251	Center of study cove at Lake of Ozarks. 1 3/8 Miles West of Gravois Arm and 2500 feet NW of its mouth with main channel.
L0-105		280252	Center of study cove at Lake of Ozarks 1 3/8 Mile West of Gravois Arm and 4000 feet Northwest of its mouth with main channel.

<u>E.P.A. Station</u>	<u>C.O.E. Station</u>	<u>STORET Number</u>	<u>Description</u>
L0-106		280253	Mouth of small cove on SE corner of study cove at Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-107		280254	End of small cove on SE corner of study cove at Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-108		280255	SE corner of small cove on NW corner of study cove at Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-109		280256	NW corner of small cove on NW corner of study cove at Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-110		280257	NW corner of study cove at Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-111		280258	North end of study cove at Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-112		280259	West edge of small cove in NE corner of study cove at Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-113		280260	East edge of small cove in NE corner of study cove at Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-114		280261	Mouth of small cove at SE corner of study cove at Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-115		280262	End of small cove at SE corner of study cove at Lake of Ozarks. 1 3/8 Mile West of Gravois Arm.
L0-116		280263	Jackson Branch Creek. 1 Mile West of County Road W at North side of Lake of Ozarks.
L0-117		280264	SW corner of Millstone Lodge cove at Lake of Ozarks.

<u>E.P.A. Station</u>	<u>C.O.E. Station</u>	<u>STORET Number</u>	<u>Description</u>
L0-118		280265	West edge of Millstone Lodge cove at Lake of Ozarks.
L0-119		280266	NW corner of Millstone Lodge cove at Lake of Ozarks.
L0-120		280267	North end of Millstone Lodge cove at Lake of Ozarks.
L0-121		280268	NE corner of Millstone Lodge cove at Lake of Ozarks.
L0-122		280269	SE corner of Millstone Lodge cove at Lake of Ozarks.
L0-123 & L0-3M		280270	Lake of Ozarks at Millstone Lodge swimming area.
L0-123A		280289	At Millstone Lodge well water pumphouse drinking water faucett.
L0-124		280271	SE end of the south Holiday Inn.
L0-124A		280314	Lake of Ozarks Holiday Inn North sewage treatment plant influent.
L0-124B		280324	Lake of Ozarks Holiday Inn North sewage treatment plant effluent.
L0-124C		280325	Lake of the Ozarks Holiday Inn South sewage treatment plant influent.
L0-124D		280326	Lake of the Ozarks Holiday Inn South sewage treatment plant effluent.
L0-125		280272	Center of the south Holiday Inn cove at Lake of Ozarks.
L0-126		280273	NE end of the south Holiday Inn cove at Lake of Ozarks.
L0-127		280274	Directly in front of Holiday Inn at Lake of Ozarks.
L0-128		280275	West end of the North Holiday Inn cove at Lake of Ozarks.
L0-129		280276	Center of North Holiday Inn cove at Lake of Ozarks.

<u>E.P.A. Station</u>	<u>C.O.E. Station</u>	<u>STORET Number</u>	<u>Description</u>
L0-9A		280277	Perkins Point 14.1 miles from Bagnell Dam upstream. 4 3/4 miles East of Sunrise Beach. NE 1/4 Sec. 34, T40N, R16W. This station is in the same cross section as COE station 11 (EPA, L0-9), STORET # 280115. Located 75% of distance from right bank looking upstream.
L0-130		280278	East end of the North Holiday Inn cove at Lake of Ozarks.
L0-131		280279	Little Gravois Creek at County Road "W" south of Versailles.
L0-132		280280	Grandglaize Arm at mouth of Anderson Hollow cove at Lake Ozarks.
L0-133		280281	Grandglaize Arm at mouth of Patterson Hollow cove at Lake of Ozarks.
L0-134		280282	Small creek draining into Prairie Hollow 8500 feet SW of Highway 5 and Highway 135 junction near the Lake of Ozarks.
L0-135		280283	Small creek adjacent to road, 8200 feet SW of Highway 5 and 135 junction near Lake of Ozarks.
L0-137		280284	Osage River at Warsaw STP effluent.
L0-137A		280313	Warsaw Sewage Treatment Plant influent.
L0-138		280285	Osage River at Highway 65 bridge crossing near Warsaw.
L0-139		280286	Minnow Brook Creek below Camdenton STP effluent.
L0-140		280287	Minnow Brook Creek at Camdenton STP effluent.

<u>E.P.A. Station</u>	<u>C.O.E. Station</u>	<u>STORET Number</u>	<u>Description</u>
LO-140A		280327	Camdenton, Missouri STP lagoon influent.
LO-141		280288	Minnow Brook Creek above Camdenton STP effluent.
LO-2-M		280295	Lake of Ozarks Millstone Lodge. Extreme south dock on the East side of the Millstone Restaurant.
LO-4-M		280296	Lake of Ozarks Millstone Lodge. Shore line where stream from LO-1-M meets in the extreme northwest corner of the cove.
LO-1-M		280297	Lake of Ozarks Millstone Lodge. Four inch clay pipe in the east cove deep in the northwest corner approximately 10 feet up the hillside above the water level.
NR-SR-32		280298	Niangua River at Missouri State Road 32 east of Buffalo.
NR-SR-64		280299	Niangua River at Missouri State Road 64 northeast of Buffalo, Missouri.
NR-Near Charity		280300	Niangua River east of Charity, Missouri.
LN-US-54		280301	Little Niangua River at 54 Highway. North of Buffalo.
NR-US-66		280302	Niangua River at U.S. Hwy 66 north of Marshfield.
LN-SR-73		280303	Little Niangua River at State Road 73 north of Buffalo.